Global population dynamics and climate change:

Comparing species-level impacts on two contrasting large mammals

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Background

- Climate change will likely cause shifts in species' distribution and abundance across the globe.
- To date, most studies of population dynamics focus on single populations of animals, over limited time –scales.
- Predictions from these population-level models fail to capture historical (Pleistocene) or current changes to species ranges (Schmitz et al. 2003).
- The mechanisms that generate **global** patterns of species distribution and abundance remain unclear (Fig. 1).

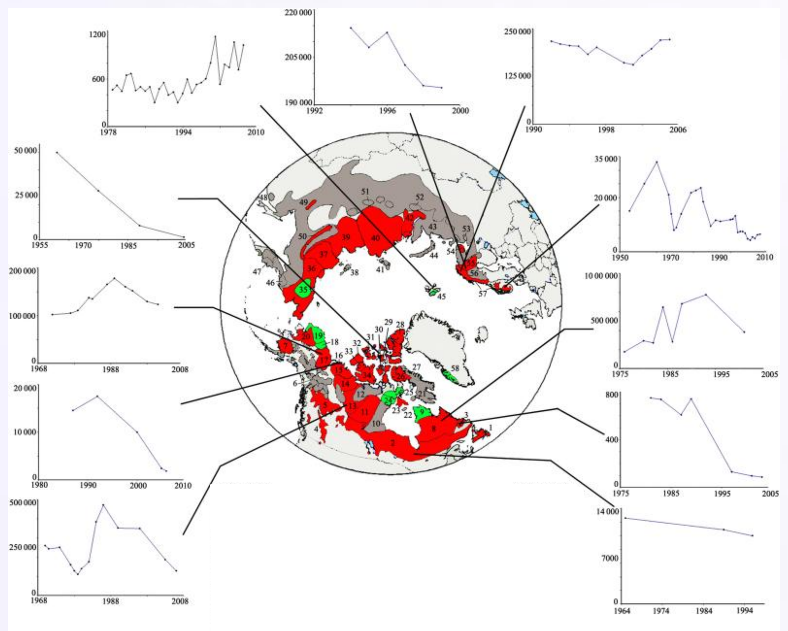


Fig. 1. Distribution and population dynamics of caribou. Populations shown in red are declining, populations shown in green are growing, while those in dark gray do not have trend data. Variation in these overall trends is shown for 11 populations with time-series of population estimates (from Vors and Boyce 2009).

- Population dynamics depend on abiotic (i.e. climate) and biotic (i.e. species interactions) factors, as well as interactions between these two mechanisms (Fig. 2).
- Populations may vary in sensitivity to biotic and abiotic factors.

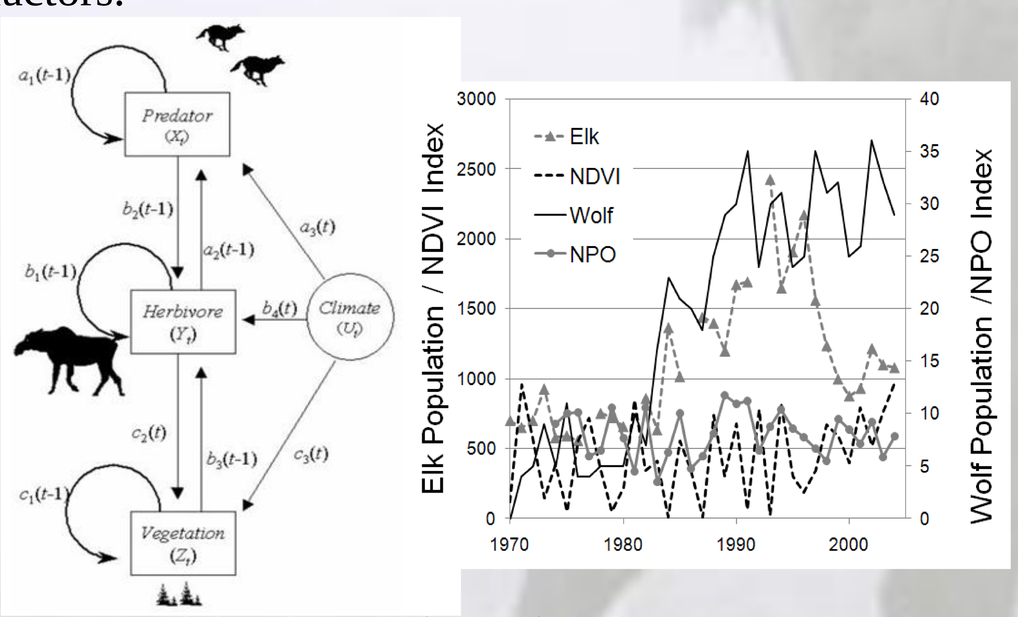
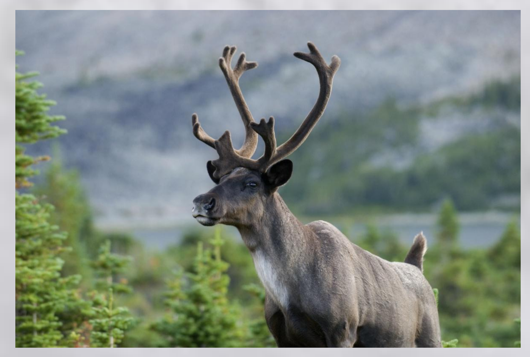


Fig. 2. Three-link trophic model for a wolf-ungulate-vegetation-climate system adapted from Post & Forchhammer (2001) where the coefficients of a time-series model of herbivore dynamics are expressed as a function of climate, vegetation and predator feedbacks. At right is an example time series for Banff National Park of wolves, elk, NDVI-index (from MODIS and AVHRR), and climate (North Pacific Oscillation) adapted from Hebblewhite (2005).

The Global Population Dynamics Approach

- Integrate time-series from multiple populations of two species with environmental data to better understand species' response to global changes (Post et al. 2009).
- We propose to apply the Global Population Dynamics Approach to >100 populations of elk (*Cervus*) and caribou (*Rangifer*) from across their global distribution, and identify populations and areas sensitive to climate change at present and in the future..

Elk (*Cervus*)



Caribou (*Rangifer*)

Research Questions

Q:1: How do landuse and climatic change affect species' niche throughout their ranges?

- Model both the fundamental and realized niche to determine what environmental factors, particularly human landuse, contribute to species' distribution and abundance (Fig. 3).
  - Fundamental niche: set of abiotic factors, regardless of biotic factors, in which a species may theoretically occur.
  - Realized niche: area where the abiotic and biotic conditions are favorable for occurrence.
- Examine the spatial and temporal relationships between remotely sensed forage availability data (e.g., NDVI) and field measures of forage biomass/quality.

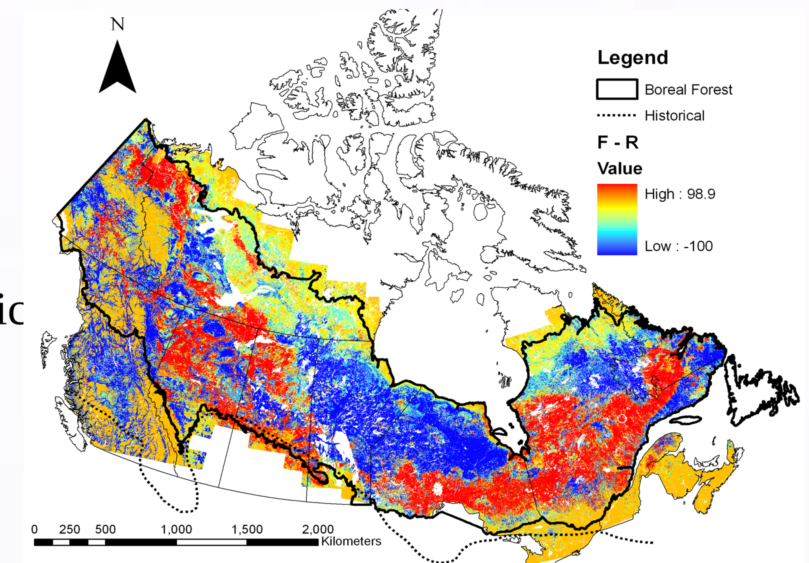


Fig. 3. Environmental Niche models for woodland caribou showing the difference between potential (climate only, fundamental) and realized (climate + anthropogenic) niche's from 1970-2000. Red areas indicate where caribou are predicted to occur based only on climate, whereas blue areas show where caribou occur because of human land use.

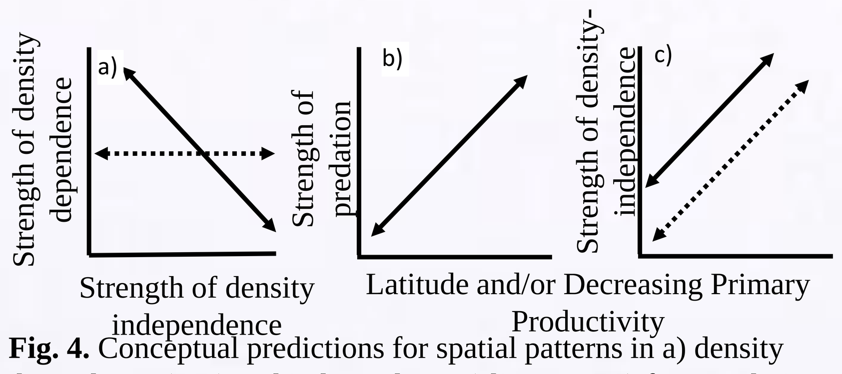


Fig. 4. Conceptual predictions for spatial patterns in a) density dependence (DD) and independence (climate - DI) for populations without predators (black) and populations with predation (dashed), b) the strength of predation and latitude and/or decreasing primary productivity where predators are present, and c) the strength of density-independence (climate) as a function of increasing latitude or decreasing primary productivity.

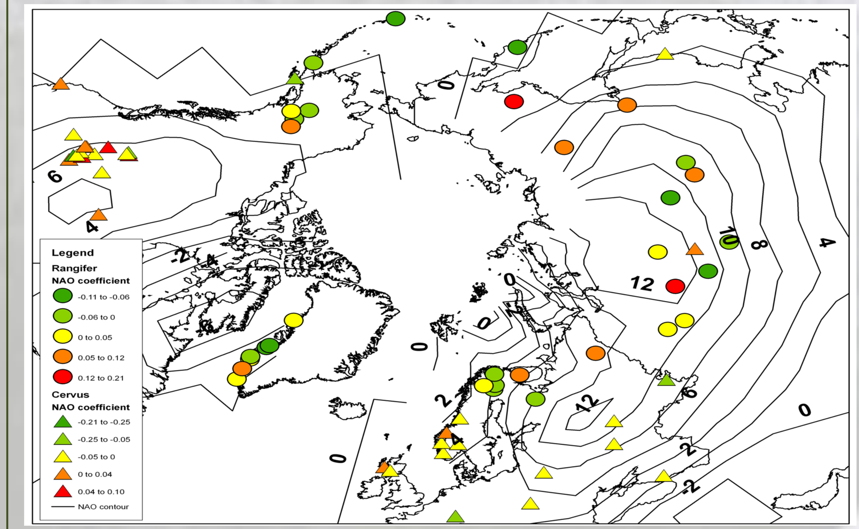
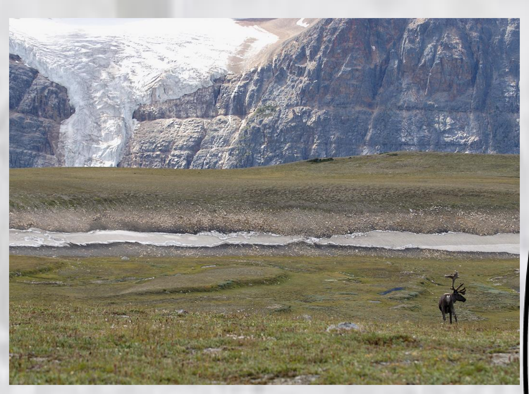


Fig. 5. Map of hot spots of response to climate for *Cervus* (triangles) and *Rangifer* (circles) showing the strength of and magnitude (green – negative, red – positive) of the correlation with Northern Hemisphere temperature anomalies (NHTA) and population growth rate. The strength of the relationship between local temperature and a +1 standard deviation (SD) change in the North Atlantic Oscillation (NAO) is shown in the contour bands; a +10 correlation indicates a 1 degree Celsius change in local temperature with a +1 SD change in NAO. From Post et al. (2009).

Q2: How does climatic influence vary across a species' range and globally after accounting for biotic interactions?

- Consider the effects of competition for forage (density-dependence), predation, forage quality and climate on population dynamics.
- Examine the interactions between predation and density, climate and density with and without predators to determine how biotic and delayed abiotic processes influence the relative impact of predation.
- Test whether the strength of density dependence varies inversely with primary productivity (Fig. 4).
- Highlight climate change hotspots by incorporating climate into population dynamics models with predation, vegetation and interactions among these terms (Fig. 5).
- Determine the relative pathway of climatic influence on ungulate population dynamics.
- Assess the direct and indirect (through predation and/or forage) effects of climate on population dynamics.
- Model the spatial and temporal responses to climatic change on a global scale.



Q3: How does the spatial scale of population synchrony vary with climate change?

- Synchrony among populations positively correlated to extinction rate (Heino et al. 1997).
- Explore the role of climate in determining synchrony across a species range .
- Determine the relative contribution of dispersal and environmental (climatic) induced synchrony in a warming climate
- Investigate change in the spatial scale of synchrony over time with climate change.

Fig 2. Conceptual diagram of research proposal linking 4 main research questions with spatial and temporal climate, landuse and remote sensing vegetation indices. We will combine results from the niche modeling (Q1) with population analyses (Q2&3) to identify current and future hotspots of species response to climate change.

Study Species

- Related, but ecologically contrasting large generalist herbivores with well-known life history.
- Circumpolarly distributed large herbivores likely to be differentially affected by climate change (Fig. 7).
- Differ in past and anticipated responses to climate change.
- Offer a powerful contrast to understand the interplay of climate and biotic factors in driving climate response

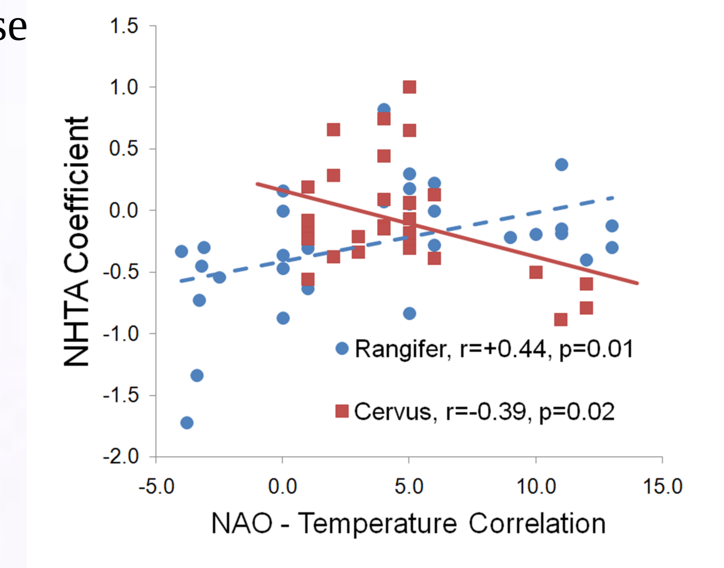


Figure 7. Contrasting effects of climate on population growth rate of two contrasting species, elk and caribou, across North America. Shown is the strength of the effect of NTHA on population growth rate as a function of the downscaling strength of the NAO local temperature relationship.

Conclusions

- Improved understanding of the mechanics of the effects of climate change on two economically important species at continental scales.
- Link global MODIS (and other) datasets to biodiversity responses to climate.
- Evaluate effects of future climate change projections (CMPI 5[th] assessment) on these two contrasting species from niche model to global population dynamics.
- Global impacts of climate on wildlife is a critical knowledge gap because of the key role wildlife play in the public's perception of climate impacts and shaping climate policy (Sponberg 2007).

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- **For more information, please contact Mark Hebblewhite at mark.hebblewhite@umontana.edu**

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